2017

The American Pediatric Type 2 Diabetes Epidemic: Considerations for Targeted Diabetes Prevention Programs

Dolores Dodson
Wright State University - Main Campus

The American Pediatric Type 2 Diabetes Epidemic: Considerations for Targeted Diabetes Prevention Programs

Dolores Dodson

Wright State University Bonshoft School of Medicine

Master of Public Health Program

Nikki L. Rogers, PhD, CPH - Committee Chair

James R. Ebert, MD, MBA, MPH, CPH - Committee Member

Acknowledgements

I would like to thank the Master of Public Health program at Wright State University for assisting in the advancement of my education surrounding public health issues. My practice placement was spent working with Nikki Rogers on the *Communities against Chronic Disease* grant, which exposed me to the Diabetes Prevention Program and efforts to expand the program locally within the Greater Dayton area.

Table of Contents

Abstract

Childhood obesity is an identified risk factor for several long-term health issues such as type 2 diabetes mellitus (T2DM). According to the Centers for Disease Control and Prevention (CDC), diabetes is the seventh leading cause of death within the United States. The CDC has implemented an evidence-based program, The National Diabetes Prevention Program (DPP), to prevent the development of T2DM among individuals with prediabetes. Prediabetes is defined as having elevated glucose levels glycated hemoglobin [A1C] levels between 5.7%-6.5%) that are not elevated enough to meet diabetes diagnosis criteria (A1C levels > 6.5%). The DPP is a lifestyle change program that has shown that the risk for developing T2DM can be reduced by 50% by increased physical activity and healthier eating practices. There has been a significant increase in T2DM within the pediatric population over past twenty years, which is greatly affected by obesity. Evidenced-based lifestyle interventions for children are important. Several programs are emerging that utilize the basis of the DPP lifestyle interventions that have been proven successful in adults in the youth population. Of these programs, Riley Children's Health *Get a Move On and Powerhouse,* University of Nevada at Las Vegas adapted DPP program, and Yale University's *Bright Bodies Management Program* have shown success in the youth population. The youth diabetes prevention program (YDPP) requires further exploration and identification of best practices to implement in school based and/or youth settings to combat the epidemic of type 2 diabetes in the youth population.

Keywords: Diabetes Prevention Program, childhood, obesity, diabetes, lifestyle change, Youth Diabetes Prevention Programs

The American Pediatric Type 2 Diabetes Epidemic: Considerations for Targeted Diabetes Prevention Programs

Diabetes mellitus (DM), commonly referred to as diabetes, is a complex metabolic disorder that occurs when the pancreas does not produce enough insulin or the body does not effectively use the insulin produced to regulate glucose levels (World Health Organization [WHO], 2016). There are two common forms of diabetes, type 1 diabetes (T1DM), formerly known as insulin-dependent or juvenile-onset diabetes, and type 2 diabetes (T2DM), formerly known as non-insulin dependent or adult-onset diabetes (WHO, 2016). Other less common forms of diabetes include gestational diabetes, neonatal diabetes, and maturity-onset diabetes of the young (American Diabetes Association [ADA], 2017). In T1DM, the body's immune system destroys insulin-producing beta cells, resulting in reduction or elimination of insulin production, which in turn reduces the ability to transport glucose across cell membranes, thus denying the cells glucose to store as glycogen, or metabolize for energy needed for daily cellular function (WebMD, 2017). T1DM is an autoimmune disorder and is, therefore, not preventable through behavioral modifications (Basile, Guy, Schwartz, & Grant, 2014). In contrast, T2DM, the most common form of diabetes, is characterized by normal or higher than normal levels of insulin, with concomitant insulin resistance due to the actions of the body's fat cells or adipocytes interfering with the action of insulin. T2DM can develop at any age and is on the rise in adults and (Romero, 2016) in children and adolescents (WebMD, 2017). T2DM is preventable through lifestyle changes including improved dietary habits and increased physical activity (Tuso, 2014).

Diabetes is a major public health concern in the United States and was the seventh leading cause of death within the United States (ADA, 2016a). Thirty years ago, T2DM was a rare diagnosis in children and adolescents. However, in the mid-1990s, investigators identified

an increasing incidence of T2DM worldwide (Reinehr, 2013) and an increase in prevalence and degree of obesity in children (6 to 11 years) and adolescents (12 to 19 years) in the United States (Reinehr, 2013). The literature indicates that in the past 40 years, obesity levels in children and adolescents in the United States have tripled (Bassett, John, Conger, Fitzhugh, & Poe, 2015). Obesity in early childhood is associated with numerous chronic conditions with childhood onset, including T2DM, hypertension, and cardiovascular disease, as well as an increased risk of remaining overweight or obese in adulthood with persistence and progression of the same chronic conditions (Zilanawala et al., 2015). The childhood obesity epidemic has led to an exponential increase in T2DM in children and adolescents (Figure 1) (Brar, Mengwall, Franklin, & Fierman, 2014).

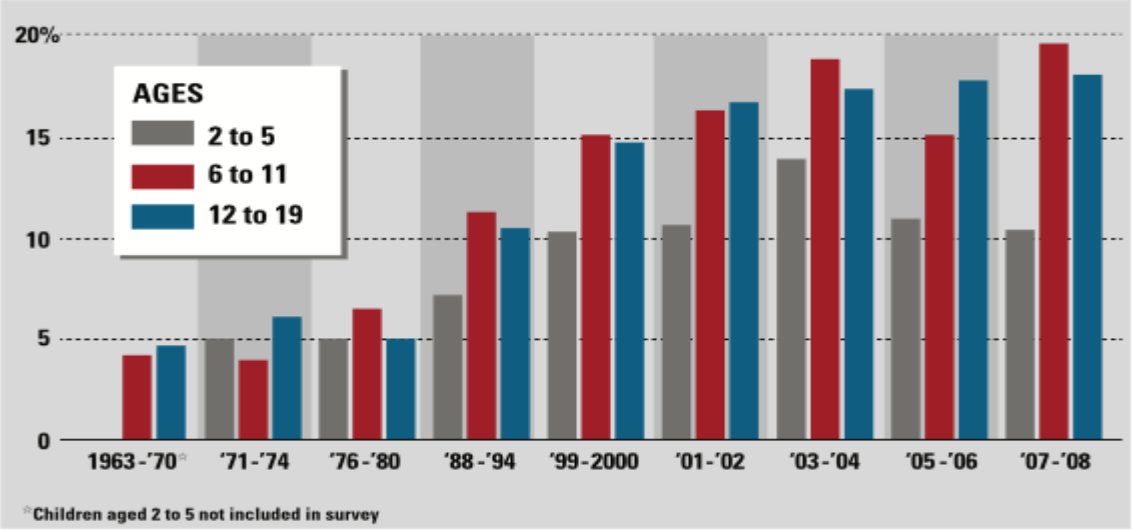

Figure 1. T2DM in children and adolescents. Copied from Romero, 2016, p. 14.

This rapid increase in T2DM in children and adolescents in the United States represents a major public health issue due to the increased risk for chronic complications including cardiovascular disease, nerve damage, kidney disease, and vision loss (Romero, 2016).

Approximately 208,000 (0.25%) Americans under the age of 20 have been diagnosed with diabetes (Centers for Disease Control and Prevention [CDC], 2015b).

There are several ongoing efforts to combat and prevent T2DM with early detection, including a recent focus on subclinical precursors to diabetes. Prior to developing diabetes, individuals often exhibit *prediabetes* (CDC, 2015a), a condition in which people have higher than normal blood glucose levels but not high enough for a diabetes diagnosis (Tuso, 2014). The National Diabetes Prevention Program (NDPP) was a major multifaceted clinical study that aimed to determine if lifestyle change (including nutrition changes and increased physical activity or the use of oral diabetes drugs) could prevent or delay the onset of T2DM (National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK], 2008). The NDPP reported that lifestyle changes resulted in weight loss that can prevent and/or delay T2DM (ADA, 2016a). The use of the oral diabetes drug *metformin* can delay the onset of T2DM as well (NIDDK, 2008).

While the NDPP has only focused its efforts at preventing the onset of diabetes in adults to date, the American Diabetes Association (ADA) now recommends screening at-risk children using fasting plasma glucose (FPG) or oral glucose tolerance test (OGTT) every two years beginning at ten years of age (Brar et al., 2014). Children that are at-risk for T2DM are identified as overweight and have a least two additional risk factors for T2DM including family history, categorized as belonging to a racial or ethnic minority, low birth weight, or maternal history of gestational diabetes during the child's gestation (Hannon, 2014). The early detection of hyperglycemia in children and/or adolescents is integral to the prevention of developing T2DM.

Statement of Purpose

The purpose of this review was to: 1) describe the pediatric epidemic of T2DM in the United States and its implications and 2) to identify evidence-based childhood/adolescent prediabetes interventions akin to the National Diabetes Prevention Program for adults. In the potential absence of appropriate existing programs the project was designed to offer recommendations for modifying the adult NDPP for the child and adolescent population.

The following sections first describe the biological basis and sequelae of diabetes and prediabetes, their treatment, and the long-term public health implications driving the current national movement for prevention. Then a review of emergent diabetes prevention programs tailored to the childhood/adolescent demographic is presented along with recommendations to improve programs to prevent the onset of T2DM in children.

Overview of Diabetes

The human body depends on food as an energy source to maintain necessary metabolic functions. Diabetes is a category of metabolic disorder negatively affecting how the human body utilizes food as an energy source (CDC, 2015a). In the human body, the pancreas creates and secretes the hormone *insulin* to metabolize glucose as an energy source for bodily function (CDC, 2015a). Individuals with diabetes have glucose levels higher than is physiologically safe, a pathological condition known as hyperglycemia (CDC, 2014). Hyperglycemia can occur due to a lack of insulin produced by the pancreas to metabolize glucose (characteristic of T1DM) or because the insulin produced is ineffective in metabolizing the glucose (insulin resistance, characteristic of T2DM) (CDC, 2014). Symptoms of hypergylcemia include any sugar excreted in the urine, frequent urination, and/or increased thirst (ADA, 2014). If left untreated, persistent hyperglycemia can lead to a serious and potentially fatal condition, *diabetic ketoacidosis* (DKA)

(ADA, 2014). DKA occurs when an excessive amount of glucose builds in the bloodstream without transport of glucose into the cells. The cells then begin to burn fat and ketogenic amino acids for energy, which produces *ketones* (ADA, 2014). Ketones are chemical byproducts produced by the breakdown of fat and ketogenic amino acids by the body for energy use (ADA, 2014). An excessive amount of ketones can cause the blood pH level to drop to acidic levels (pH < 7) from the usual slightly basic pH (pH = 7.35 – 7.45) (American Association for Clinical Chemistry, 2014). This acidification can cause negative cardiovascular and respiratory complications including hypertension, stroke, and nephropathy (ADA, 2014).

T1DM

There are two main types of diabetes, T1DM and T2DM. T1DM, previously known as juvenile diabetes, is an autoimmune disorder in which insulin-producing cells of the pancreas known as *beta cells* are attacked, preventing the production of insulin (Juvenile Diabetes Research Foundation [JDRF], n.d.). Due to lack of insulin production, individuals with T1DM have higher than recommended glucose levels in the body. T1DM is often characterized by an acute onset and presents with symptoms including unexplained weight loss, sweet odorous breath, increased thirst, increased appetite, change in mental status, and/or labored breathing (JDRF, n.d.). Individuals with T1DM manage their glucose levels with administration of insulin, eating a balanced diet at regular intervals, regulating carbohydrate intake, and moderate physical activity throughout the day (JDRF, n.d.).

T2DM

The most common form of diabetes is T2DM: it makes up roughly 90% of all diagnosed diabetes cases in the United States (The Obesity Society, 2016). This particular form of diabetes is characterized by elevated blood glucose levels due to the impaired function of insulin

produced by the pancreas also known as *insulin resistance* (NIDDK, 2014). *Insulin resistance* is a condition in which adipocytes excrete chemical mediators that interfere with the intended action of insulin. The pancreatic islet cells compensate by producing more insulin to facilitate transport of glucose into muscle, liver, and fat cells (NIDDK, 2014). Over time there is gradual attrition of the overworked islet cells in the pancreas, and the organ becomes unable to produce enough insulin to satisfy the increased cellular need, resulting in sustained elevation of blood glucose levels (NIDDK, 2014).

Prediabetes

In 2002, the ADA defined prediabetes as impaired fasting glucose (IFG) and/or impaired glucose tolerance (IGT) (ADA, 2013). IFG is defined as having a fasting blood glucose of 100 to 125 mg/dl (after minimum fast of 8 hours) and IGT is defined as glucose level from 140 mg/dl to 199 mg/dl measured two hours after consuming a glucose-rich drink of specific dose (ADA, 2013). The glycosolated hemoglobin (A1C) test is the primary test used for diabetes management and research. This test is based on the rate of glucose to hemoglobin, the protein in red blood cells that carries oxygen (NIDDK, 2014). (The A1C diagnostic test and ranges are described more fully in the following section.) Individuals that have high blood glucose or hemoglobin A1C levels (between 5.7%-6.4%) are diagnosed with prediabetes (NIDDK, 2014).

In 2012 it was reported that 86 million adult (> 20 years) Americans had prediabetes, an increase from the 2010 report of 79 million prediabetic adults (ADA, 2016b). A diagnosis of prediabetes is an indication that an individual is at greater risk than non-prediabetic individuals to develop T2DM (CDC, 2016c).

Due to the associated chronic health risks with prediabetes, surveillance of prediabetes allows for better prediction of diabetes trends (Abraham & Fox, 2013). Similarly, the clinical

diagnosis of prediabetes allows for the identification of individuals that are more susceptible to develop T2DM. Both lifestyle changes and metformin can independently delay the progression from IGT to diabetes (Abraham & Fox, 2013). Identification of individuals with prediabetes offers them the opportunity to modify their risk prior to the development of significant sequelae (Abraham & Fox, 2013).

Hyperglycemia Categorization in Adults and Youth

While hyperglycemia can present with a variety of symptoms (e.g. frequent urination, increased thirst, fatigue, blurred vision), the standard method for diagnosing hyperglycemic conditions is through clinical blood tests (NIDDK, 2014). The standards used for youth (6 to 11) and adolescents (12 to 18) are the same as adults. The three most common hematological laboratory tests used for diagnosis of hyperglycemia are: glycosolated hemoglobin (A1C), fasting plasma glucose (FPG), and the oral glucose tolerance test (OGTT) (NIDDK, 2014). The same tests are used to screen for and diagnose diabetes and identify individuals with prediabetes (ADA, 2016c). Figure 2 summarizes the parameters for diagnosis of prediabetes and diabetes for each of the diagnostic tests.

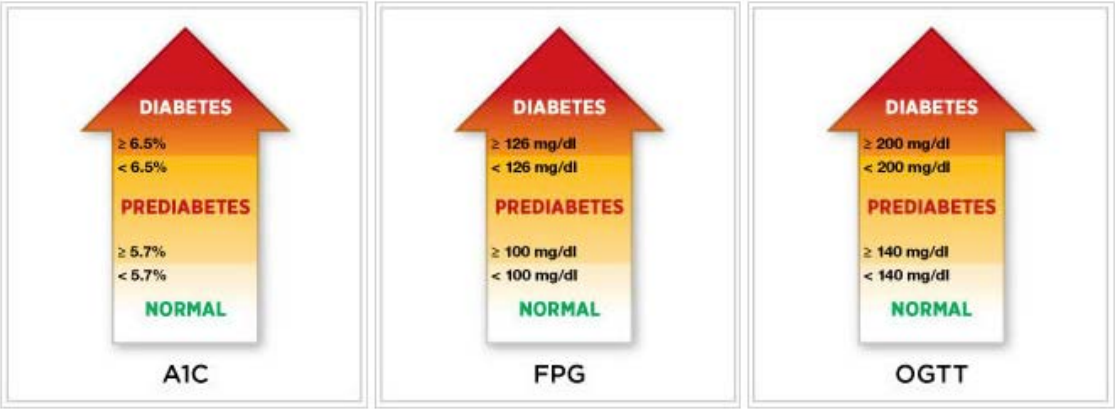

Figure 2. Diagnostic test ranges for diabetes. Source: American Diabetes Association, 2016c, "Diagnosing diabetes and learning about prediabetes".

Hemaglobin A1C Test

The A1C test reflects an individuals' average blood glucose over the past two to three months (ADA, 2014). In the human body, red blood cells are constantly forming and dying, but typically live for three months. Thus the A1C test reflects the average of a person's glucose over the past three months (NIDDK, 2014). A normal A1C level is defined as greater than > 5.7%; an A1C level that indicates prediabetes falls within range of the normal and diabetic A1C (5.7% < 6.5%); and an A1C level that indicates diabetes is greater than the prediabetic range (≥ 6.5%) (NIDDK, 2014). In contrast to the FPG, there is a greater cost associated with the A1C test (ADA, 2016c), but there are several advantages to utilizing the A1C test for prediabetes/diabetes diagnosis. These advantages include no requirement to fast, greater pre-analytical specimen stability, and less day-to-day fluctuation due to stress and/or illness (ADA, 2016c).

Fasting Plasma Glucose (FPG) Test

A fasting plasma glucose (FPG) test directly measures the blood glucose quantified a milligrams per deciliter of blood (Mayo Clinic, 2014). The test requires that an individual refrain from consuming food or drink, with the exception of water (*fast*) for at least eight hours

prior to the test (ADA, 2014). An FPG level of 100 mg/dl is considered normal. Prediabetes is diagnosed with an FPG level 100 mg/dl to125 mg/dl (100 mg/dl < 125 mg/dl) and diabetes is diagnosed as an FPG level greater than or equal to 126 mg/dl (≥ 126 mg/dl) (ADA, 2014). If a level greater than 126 mg/dl is indicated in the initial test, a second test is performed to confirm the diabetes diagnosis (NIDDK, 2014). The FPG test has been the most common test used for the diagnosis of diabetes because it is more convenient and less expensive than the OGTT (NIDDK, 2014).

Oral Glucose Tolerance Test (OGTT)

The oral glucose tolerance test (OGTT) measures serial blood glucose levels after an individual fasts for at least eight hours and again two hours after consuming a drink containing 75 g glucose dissolved in water (NIDDK, 2014). This protocol describes how the body processes glucose (ADA, 2014). A two-hour OGTT reading of less than 140 mg/dl is defined as normal (< 140 mg/dl); a reading of 140 mg/dl to 199 mg/dl indicates a diagnosis of prediabetes (140 mg/dl < 199 mg/dl); and a reading greater than 200 mg/dl indicates a diagnosis of diabetes (≥200 mg/dl) (ADA, 2014). The OGTT can be used to diagnose all categories of diabetes. Research has shown that the OGTT is more sensitive indicator of the risk of developing T2DM in comparison to the A1C and FPG, but it is less convenient to administer due to its strict preliminary requirements (NIDDK, 2014).

T1DM Diagnosis and Treatment

All three diagnostic tests (A1C, FPG, and OGTT) can be utilized to diagnose T1DM in all age groups (NIDDK, 2014). However, T1DM is most commonly diagnosed by a random plasma glucose with a test value of greater than 200 mg/dl (ADA, 2016a). A random blood glucose test can be administered at any time to check the blood glucose levels within a patient's

body. Regardless of the time since an individuals' last meal, a random blood sugar level greater than 200 mg/dl suggests diabetes (Mayo Clinic, 2014).

The A1C test is often used to *screen* for T1DM due to the lack of fasting needed to administer the test. However, it is not recommended for the *diagnosis* of T1DM (NIDDK, 2014). The epidemiological studies that formed the basis for recommendations for the A1C test to diagnosis diabetes only included adults; it is therefore unclear if A1C and its respective diagnostic cut points should be utilized for diagnosing T1DM in children and adolescents (ADA 2017). Nevertheless, the A1C test is often still utilized for the testing of T1DM. If this test is unavailable or not chosen, an FPG or random blood glucose test can be administered as well test (Mayo Clinic, 2014).

A patient with hyperglycemia and symptoms characteristic of diabetes must be accurately categorized as having T1DM or T2DM in order to be prescribed appropriate treatment. In order to categorize the type of diabetes mellitus a blood test is administered; if autoantibodies and/or ketones are present T1DM is suggested (Mayo Clinic, 2014).

In some cases the onset of T1DM presents with an episode of DKA followed by a symptom free "honeymoon period," where symptoms subside for weeks, months, and in some cases a few years (Khardori, 2016, Approach Considerations, second paragraph). This remission is caused by a partial return of endogenous insulin secretion; although the symptoms subside for a period of time, ultimately the disease returns (Khardori, 2016).

As there is no cure for T1DM, individuals with this diagnosis rely on lifelong insulin therapy (Khardori, 2016). After the diagnosis, patients should maintain regular medical supervision in order to reduce A1C levels in accordance with their set diabetes treatment plan (Mayo Clinic, 2014). Individuals with T1DM monitor glucose levels by pricking their finger to

test several times (3 to 6) a day (JDRF, n.d.). People with this disease must carefully balance insulin through needle injections several times a day or continuous infusion through a pump with eating and physical activity (JDRF, n.d.).

In addition to T1DM, there exists another form of DM known as latent autoimmune diabetes adults (LADA) and often referred to as *type 1.5 diabetes mellitus* (Basile et al., 2014). LADA is a slower progressing form of T1DM because of the similar autoimmune destruction of pancreatic beta cells and is often indistinguishable from T2DM due to its adult onset (Basile et al., 2014). T2DM occurs when the body is not able to use insulin properly, a condition called *insulin resistance* (WebMD, 2017).

T2DM Diagnosis and Treatment

Similar to T1DM, all of the diagnostic tests (A1C, FPG, and OGTT) can be administered to diagnose T2DM. The A1C test is often used to diagnose diabetes. However, if an individual is pregnant and/or has irregular hemoglobin (known as *hemoglobin variants*), which may alter the results of the test. The FPG or OGTT are strong alternatives to test for T2DM in such cases (Mayo Clinic, 2014).

Although T2DM can present with some similar symptoms as T1DM including increased thirst, increased urination, blurry vision, numbness in extremities (ADA, 2015), it does not exhibit an autoimmune destruction of beta cells within the pancreas or sudden onset of DKA (ADA, 2016a). Obesity is a major indicator of the susceptibility to T2DM in the United States (The Obesity Society, 2016) and is the hallmark of T2DM in North American children (Hannon & Arslanian, 2015). The escalating rates of obesity the general population means that individuals with T1DM are also more likely to be overweight/obese, making the clinical distinction between T2DM and obese T1DM difficult (Hannon & Arslanin, 2015).

In people who do not undergo periodic medical checkups, T2DM may go undiagnosed for long periods of time because hyperglycemia develops gradually and symptoms may be difficult to detect (ADA, 2016a). There are several risk factors associated with T2DM including age, race, pregnancy, stress, genetics, and family history (The Obesity Society, 2016). Most individuals with T2DM are overweight or obese (ADA, 2017). According to the 2016 Standards of Medical Care in Diabetes, testing for prediabetes and/or diabetes should be considered in adults of any age with a BMI (body mass index) greater than 25 who also exhibit one or more additional risk factors (ADA, 2016a). Testing for prediabetes and/or diabetes is recommended for children that are considered overweight (BMI > 85^{th} percentile for age) that exhibit two additional risk factors including family history, belonging to a racial/ethnic minority, maternal history of diabetes, and/or onset of puberty (ADA, 2016a).

Approximately 90% of people living with T2DM are overweight or obese; the single best predictor for T2DM is overweight or obesity defined by body mass index (The Obesity Society, 2016). The BMI is a ratio of weight to height (kg/m^2) utilized to measure the degree of an individual's overweight or obesity (CDC, 2015c). According to the CDC, BMI ranges for adults are defined as normal (BMI range 18.5< 25), overweight (BMI range 25.0 < 30) and obese (BMI ≥ 30) (CDC, 2016c). The risk of developing T2DM increases with age, obesity, and lack of physical activity (ADA, 2016a). Figure 3 shows the correlation of prevalence rates of obesity and T2DM diagnosed in US adults (Romero, 2016).

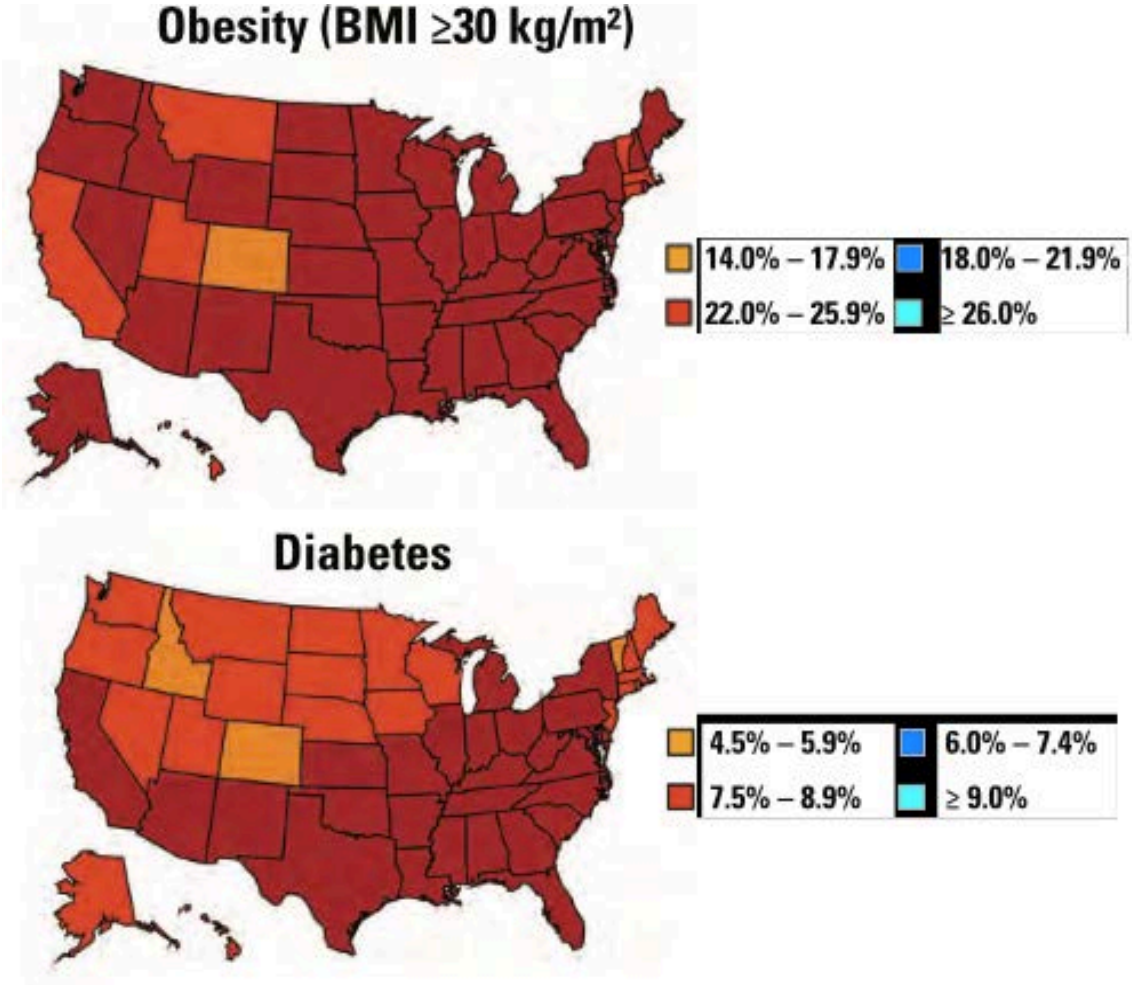

*Figure 3***.** Prevalence rates of obesity and diagnosed diabetes among US Adults. Copied from Romero, 2016, p. 14.

Management of T2DM includes healthy heating, regular exercise, and regular blood glucose monitoring, with or without oral medication or insulin therapy (Mayo Clinic, 2016). One of the most commonly prescribed medications for T2DM is *metformin*, which helps the body use insulin more effectively, basically reversing insulin resistance by facilitating transport of glucose into cells (Mayo Clinic, 2016). Other common treatments are *sulfonylureas* and *meglitinides*, classes of medications that stimulate the pancreas to secrete more insulin (Mayo Clinic, 2016).

Prediabetes Diagnosis and Treatment

Prediabetes is defined as a condition in which individuals display higher blood glucose levels than normal, but not high enough to be classified as diabetes (ADA, 2016a). Individuals with certain risk factors have a greater likelihood to develop prediabetes and/or T2DM. These risk factors include age (especially > 45 years), being overweight (BMI range 25 <30) or obese (BMI ≥30), family history of diabetes, certain racial/ethnic ancestry, and physical inactivity (active < 3 times a week) (CDC, 2016c). Being overweight and/or obese plays a large role in the progression of an individual from normal glucose tolerance (NGT) to the impaired fasting glucose (IFG) and subsequent hyperglycemia that characterizes prediabetes (D'Adamo & Caprio, 2011).

An individual with prediabetes has a greater risk for developing T2DM and other serious health complication such as heart disease and stroke: early detection and prevention efforts combat these adverse health effects (CDC, 2016c). Blood tests including A1C, FPG, and OGTT are valuable tools to diagnose prediabetes because symptoms may not be noticeable to the individual (NIDDK, 2014). Early detection of prediabetes is key to long-term health because lifestyle modifications and/or medications have been proven effective methods for reversing prediabetes and restoring normal glucose tolerance (NGT) (Brar et al., 2014).

Diabetes Morbidity and Mortality

While diabetes is recognized as a major international public health risk, according to the International Diabetes Federation (IDF), the highest prevalence (11.5%) is reported in North America and the Carribean (Jaacks, Siegel, Gujral, & Narayan, 2016). Although preventable, diabetes remains a growing public health epidemic in the United States. In 2012, 29.1 million Americans had diabetes, which increased from the 2010 estimate of 25.8 million Americans with

diabetes (ADA, 2016b). Of the 29.1 million Americans living with diabetes, only 1.25 million (4.29%) American children and adults have T1DM (ADA, 2016b). Figure 4 illustrates the increasing prevalence of diabetes among adults ages 18 and over in the United States over the past several decades.

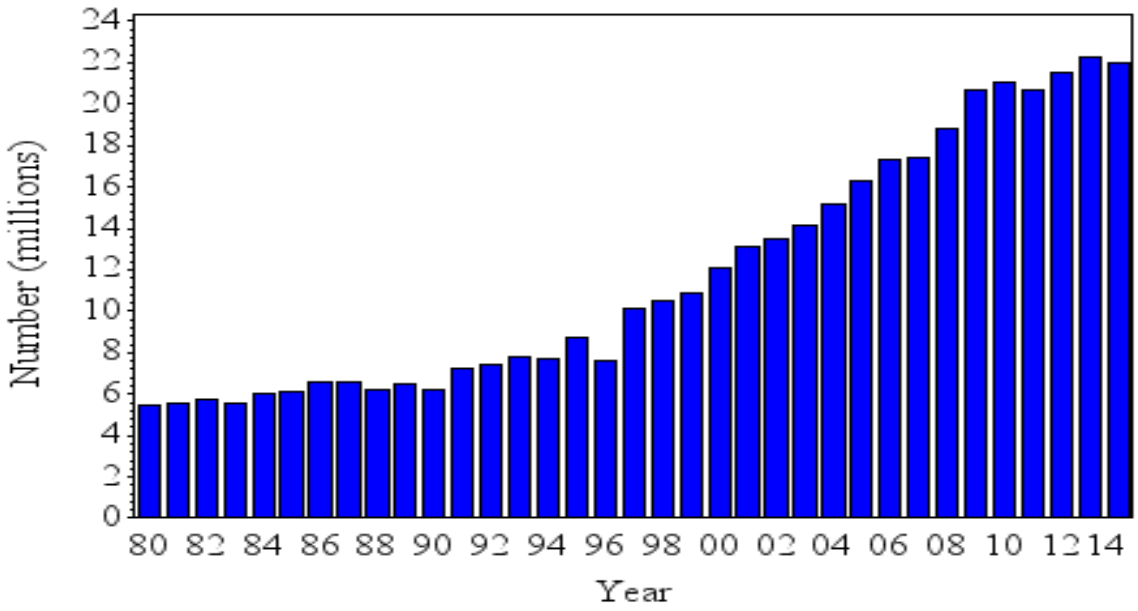

Figure 4. Adult diabetes prevalence in the United States 1980-2014. Source: CDC, 2014, p. 1.

According to the CDC, T2DM accounts for majority (90-95%) of all diabetic cases (ADA, 2016b). The severity of this disease is due to its increased risk factors for comorbid conditions including cardiovascular disease, stroke, blindness, kidney disease, and amputations (NIDDK, 2014). Of these long-term health complications, T2DM is the leading cause of blindness (diabetic retinopathy), end stage kidney disease (diabetic nephropathy), and non-traumatic lower extremity amputations (diabetic neuropathy) (The Obesity Society, 2016). Along with increased risk for adverse health outcomes, individuals with T2DM have a greater risk (50% higher) of death in comparison with individuals that do not have diabetes (CDC, 2016c); because of this, diabetes is recognized as the seventh leading cause for death among adults within the United States (CDC, 2015a).

Diabetes Catastrophe and the Need for Prevention

Due to the increased burden of T2DM and its associated complications on health outcomes, increased efforts to prevent T2DM have begun to identify at-risk individuals prior to diabetes diagnosis (Abraham & Fox, 2013). Research clearly shows that if individuals with prediabetes lose a modest amount of weight (5-7%) and increase physical activity (≥150 minutes each week), they can delay or prevent the onset of T2DM (CDC, 2016b). Without weight loss and increase in physical activity, 15-30% of individuals with prediabetes will develop T2DM within five years (CDC, 2016b). Epidemiological and clinical trials have shown that the onset of T2DM can be also delayed and/or be prevented through pharmacological intervention (Kong, Luk, & Chan, 2016).

Due to the largely preventable nature of T2DM (The Obesity Society, 2016), multiple organizations have provided screening recommendations for T2DM for adults. These include The United States Preventive Services Task Force (USPSTF, https://www.uspreventiveservicestaskforce.org/) and the American Diabetes Association (ADA, http://www.diabetes.org/) (Pippitt, Li, & Gurgle, 2016). The USPSTF recommends screening adult individuals aged 40 to 70 years that present as overweight or obese based on BMIs (Pippitt et al., 2016). In contrast, the ADA recommends broader screening, including adults 45 years of age or older *regardless of risk*, and they also include screening for prediabetes in their guidelines (Pippitt et al., 2016). In order to address the magnitude of this disease, the CDC has implemented an evidenced-based program, *The National Diabetes Prevention Program* to prevent or delay the development of T2DM among adults with prediabetes (CDC, 2016b).

The National Diabetes Prevention Program (DPP)

The Diabetes Prevention Program was a multifaceted clinical research study established compare behavioral and pharmaceutical interventions including modest weight loss (5-7% body weight) through dietary changes and increased physical activity or pharmacological treatment with oral diabetes drug metformin in the prevention and/or delay of onset of T2DM in participants (NIDDK, 2008). At baseline, study participants (n = 3,234) were all categorized as overweight and had prediabetes, which are known risk factors for the development of T2DM (NIDDK, 2008). In addition, many participants (45%) were from minority groups (African American, Alaska Native, American Indian, Hispanic/Latino or Pacific Islander) all of whom are at increased risk for developing T2DM (NIDDK, 2008). The participants were divided into four groups: lifestyle intervention, metformin, placebo, and troglitizone group; the troglitizone group was later discontinued when the drug was removed from the market due to adverse side effects including liver damage (NIDDK, 2008). The DPP's results indicated that participating individuals at-risk for developing T2DM reduced their risk by 58% with only increased physical activity and dietary modifications, making pharmaceutical intervention optional (NIDDK, 2008). Along with the lifestyle intervention, the DPP also reported that metformin alone can also be effective in helping delay the onset of diabetes (NIDDK, 2008).

In order to combat the rising epidemic of prediabetes and T2DM, the CDC introduced the evidenced-based lifestyle intervention The National Diabetes Prevention Program (NDPP, https://www.cdc.gov/diabetes/prevention/index.html). The NDPP is a year-long lifestyle intervention program providing educational sessions, homework and feedback from a lifestyle coach to optimize behavioral modifications and achieve 5-7% weight loss from baseline (CDC, 2016b).

The program can be disseminated at any CDC-approved location that has taken the proper steps to maintain fidelity and accuracy of disseminating the program according to CDC DPP curriculum CDC (CDC, 2016b). The program is 12-month-long program with the initial six months covering 16 lifestyle intervention topics and the last six months covering at least 10 additional modules (CDC, 2016b). The curriculum is delivered by DPP trained lifestyle coaches. Although academic or medical credentials are not required, some lifestyle coaches may have the following credentials: registered nurse (RN), registered dietician (RD), or certified diabetes educator (CDE) (CDC, 2016b). Program attendance, physical activity minutes, food journals, and BMI are measured to determine if program goals (moderate weight loss and increased physical activity) are met to deter the onset of T2DM (CDC, 2016b).

Due to increased research and awareness of prediabetes as well as the evidenced-based nature of the NDPP, the CDC has made the curriculum materials readily available for community organizations (https://www.cdc.gov/diabetes/prevention/lifestyle-program/curriculum.html) to adopt the evidenced-based approach to combat prediabetes and T2DM at a local level.

Prediabetes is now a treatable condition and has an ICD-10 code (R73.09) for clinical medical diagnosis and reimbursement purposes (CDC, 2016a). The adoption of a code for both diagnosis and reimbursement has increased the ability for local organizations to disseminate and deliver DPP program to combat prediabetes and assist in delaying the onset of T2DM.

The Medicare Diabetes Prevention Program (MDPP) is an expanded model that utilizes structured behavioral change intervention to prevent T2DM among Medicare beneficiaries diagnosed with prediabetes (Centers for Medicare & Medicaid Services [CMS], 2016). The MDPP was approved for Medicare reimbursement in 2016 and will be reimbursable on or after

January 1, 2018. In 2016, Medicare spent an estimated amount of $1,500 more on Part D prescription drugs, $3,100 more for hospital and facility services, and $2,700 more in physician and other clinical services for those with diabetes in comparison with those without diabetes (CMS, 2016). The expansion of coverage for the MDPP will assist in the ability to prevent T2DM in American and assist in the public health crisis of T2DM which is so costly among the American health care system.

Pediatric T2DM Epidemic Overview

The rise of T2DM in the pediatric population and its long-term health risks are important to address due to their effect on the overall health and life expectancy of today's children and adolescents. While traditionally T2DM is diagnosed after the age of forty, recently it is being diagnosed in all age ranges, including during childhood and adolescence (The Obesity Society, 2016). The incidence of T2DM in children and adolescents has increased, with a current estimated incidence of 5,000 new cases per year (Nadeau et al., 2016). Recent studies in childhood and adolescents populations have identified that children and adolescents with T2DM have an elevated risk for diabetes-related complications earlier in the course of the disease (Hannon, 2014). In the adult population, the transitional prediabetic state of IGT is associated with a high incidence (~10%) of vascular complications (D'Adamo & Caprio, 2011). However, there has been major progress with lifestyle and/or pharmacological interventions that may reverse and/or delay the onset of T2DM in adults (D'Adamo & Caprio, 2011). Thus it is important to understand the development of T2DM in youth and its complications in the pediatric population to identify best practices to achieve the same success.

Youth Onset Prediabetes and T2DM and Categorization

Similar to the adult population, the onset of T2DM is a gradual progression mainly affected by pancreatic decline in beta cell function (D'Adamo & Caprio, 2011) and/or insulin resistance (Hannon & Arslanian, 2015). Insulin resistance places an increased demand for pancreatic beta-cells to hypersecrete insulin, thereby increasing the risk for progressive beta-cell failure characteristic of T2DM (D'Adamo & Caprio, 2011). The transition from NGT to T2DM is preceded by an intermediate state of prediabetes, which is a risk factor for developing T2DM (Hannon & Arslanian, 2015). Children and adolescents that have prediabetes are classified as having IFG (FPG levels 100 – 125 mg/dL) or IGT (glucose values from OGTT of 140 –199 mg/dL) (Hannon & Arslanian, 2015). It has been proposed that hyperglycemia may worsen insulin resistance and decreased beta-cell function, therefore increasing the risk of transitioning from IGT to T2DM (Reinehr, 2013). While the transition from prediabetes to T2DM in adults is usually a gradual process (5 to 10 years), meanwhile in youth there has been an increased premature onset of T2DM observed which contributes to the notion of an accelerated process in the pediatric demographic, exhibited by a shorter transition time between IGT and the development of T2DM (D'Adamo & Caprio, 2011). The shorter duration of the prediabetes phase in youth increases the need to better understand the causes of T2DM in the pediatric demographic and the need to develop successful preventions.

Much like the adult population's risk factors for T2DM, obesity is a major risk factor for T2DM in United States youth (Hannon & Arslanian, 2015). This is alarming due to obesity being identified as one of most important causes of the development of insulin resistance (D'Adamo & Caprio, 2011). Common descriptors of a child diagnosed with T2DM are having a genetic family history, being overweight and/or obese, entering puberty, being from an

ethnical/racial minority group, and being biologically characterized as a female (Hannon & Arslanian, 2015). These descriptors are important risk factors to address to limit the gaps in research in understanding the youth onset of T2DM and to identify evidenced-based methods to prevent the development of T2DM in youth. The ADA recommends screening at-risk children for prediabetes and/or T2DM using the FPG or OGTT test every two years beginning at the age of ten and/or the onset of puberty (Brar et al., 2014).

The same screening tests used for diagnostic purposes in the adult population can be utilized to diagnose prediabetes and/or T2DM in youth. Although the FPG test is the preferred method, the OGTT test is more sensitive due to its ability to detect individuals with IGT (> 140 mg/dl), which is a major predictor of T2DM in youth (Brar et al., 2014). The requirement to fast for both the FPG and the OGTT can make it difficult for pediatricians to obtain accurate results given high rates of patience non-compliance; thus the A1C test has been considered an alternative method to test (Brar et al., 2014). A substantial amount of diagnostic criteria for T2DM is based on long-term health outcomes and validations for specific criteria that f is not available or pediatric populations (ADA, 2016a). Although the A1C test is recommended for adults, many pediatric health screeners use the adult cutoffs for FPG, A1C and OGTT tests due to the lack of research on pediatric population diagnostic criteria (Brar et al., 2014).

Modifiable Risk Factors

A major modifiable risk factor for T2DM among youth is obesity (Hannon & Arslanian, 2015). According to the World Health Organization (2016), childhood obesity is one of the largest public health challenges to face in the 21st century. The BMI is calculated by a person's weight (kg) divided by their height squared (m^2). In the pediatric population (2 to 20 years), BMI interpretation is age- and sex-specific and expressed as a percentile placement within the

patient's cohort (CDC, 2015c). In the pediatric population, a child with a BMI classified as overweight falls within the 85th and 95th percentile (85th < 95th percentile) and with a BMI greater than or equal to 95th percentile ($\geq$ 95th percentile) are considered obese (CDC, 2016c). Approximately 17% of American children are obese (CDC, 2014). Children that are overweight and/or obese are more likely to continue to be overweight and/or obese in adulthood, develop long term health issues such as diabetes, hypertension and cardiovascular diseases at a younger age, and have a greater risk of premature death (WHO, 2016). An estimated 25% of children and 21% of adolescents that are obese (BMI > 95th percentile) were found to have IGT (D'Adamo & Caprio, 2011).

The pediatric population exhibits similar patterns of transition from NGT to IGT that has been identified in the adult population due to overweight and/or obesity (ADA, 2013). Therefore, the already increasing public health risk of childhood obesity is contributing to another rising epidemic of increased presence of T2DM in children.

Lifestyle habits including excess nutritional intake and decreased physical activity (Hannon & Arslanian, 2015) are also modifiable risk factors that contribute to obesity, thus contributing to T2DM. According to a statement issued by the United States Surgeon General about childhood obesity, improper nutrition and inadequate physical activity are contributing factors for the United States childhood overweight and obesity epidemic (The Office of Disease Prevention and Health Promotion [ODPHP], 2017a). The rise in obesity, metabolic syndrome, and diabetes has increased with the increase in daily caloric intake, especially among those eating a western diet that is high in total fat and saturated fatty acids (Cree-Green, Triolo, & Nadeau, 2013). The majority of Americans also exceed recommended amounts for sugar, saturated fats, and sodium consumption (ODPHP, 2017b). According to the *Dietary Guidelines*

for Americans 2015-2020, about 1/3 of the population have eating patterns low in vegetable and fruit consumption as well as necessary dairy and oils (ODPHP, 2017b). Risks for metabolic syndrome have shown a decrease in diets high in fruits, vegetables and whole grains (Cree-Green et al., 2013). The Dietary Intervention Study in Children (DISC) evaluated the effects of a low fat, high fiber diet during adolescence and showed benefits in both glycemic control and blood pressure (Cree-Green et al., 2013).

Regular physical activity in children and adolescents contributes to a healthier lifestyle and lowers the risk for development of chronic disease (ODPHP, 2017a). However, in the United States there has been a recent decrease in overall physical activity level, especially in girls, during their transition from childhood to adolescence which is an important time in which overweight youth are at risk for developing T2DM (Cree-Gree et al., 2013). According to the *Physical Activity Guidelines for Americans* (PAG), children and adolescents ages six to17 years are recommended to perform one hour or more of physical activity per day, including aerobic-, muscle-, and/or bone-strengthening activity (ODPHP, 2017a). Sedentary lifestyle has been identified as a critical factor for the development of T2DM in youth (Cree-Green et al., 2013).

There have been several studies conducted to identify best practices in childhood obesity prevention; such studies have addressed intervention targets of diet, physical activity, and environmental components and its efficacy. The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) launched an evidenced-based program called *Ways to Enhance Children's Activity and Nutrition* (WE CAN) to combat childhood obesity by encouraging healthier nutrition, increased physical activity, and reduced sedentary activity (Zoorob et al., 2013). This intervention takes a community level approach, informing community officials, parents, and caretakers, and youth ages eight to thirteen (Zoorob et al., 2013). This community

level approach is essential because a child's environment and adult figures play an integral role in the food choices made available for children. Lifestyle changes including increased physical activity, decreased consumption of sugars, and improved overall diet are useful in combatting unhealthy weight gain. Adult healthy lifestyle choices and behaviors are traditionally developed in adolescence (Kelly, Melnyk, Jacobson, & O'Haver, 2011). Parents can play a large role for younger children and their diet and physical activity behaviors by increasing healthy food access and limiting use of technology (Evans et al., 2016). Adolescents rely less on parental figures to provide avenues for healthy living and begin to make more independent choices about physical activity and nutrition (Kelly et al., 2011). Several studies identified peer relationships and school environment as important factors that influence healthy lifestyle choices and behaviors in adolescence (Kelly et al., 2011). School based interventions have been useful in preventing childhood obesity (Evans et al., 2016). The educational environment has the ability to provide nutritional education, physical activity, healthier food access, and also may influence parental involvement by educating parents during parental events (Evans et al., 2016).

Non-Modifiable Risk Factors

Non-modifiable risk factors for T2DM in youth include a strong family history, a mother with gestational diabetes, minority groups and puberty (Hannon & Arslanian, 2015). It has been reported that adults with one parent (first-degree relationship) with T2DM have a an increased risk (30-40%) lifetime risk of developing T2DM, and individuals with two parents with T2DM have an even greater risk (70%) for developing T2DM (Hannon & Arslanian, 2015). Evidence from both animal and human studies also suggests an association of maternal obesity and gestational diabetes mellitus with an increase in offspring's obesity and T2DM in youth (Hannon & Arslanian, 2015).

Belonging to a racial/ethnic minority group has been long identified as a risk factor for many chronic diseases. In the United States, American Indians (this term is used by the United States Census) have the highest rates of youth-onset T2DM (Nadeau et al., 2016). While T2DM occurs in all racial/ethnic groups, in the SEARCH study the incidence of T2DM among children and adolescents varied by ethnicity, with some of the highest rates observed among youth (which they defined as 15 to19 years) in minority populations (African Americans, Hispanics, and Native Americans) (D'Adama & Caprio, 2011).

Puberty has also been identified as a major role in the development of T2DM in children due to the increased resistance to the action of insulin (*insulin sensitivity*) (Reinehr, 2013). During puberty, significant physiological changes occur, including up to an approximately 50% reduction in insulin sensitivity in lean, healthy children (Nadeau et al., 2016). Puberty is therefore a vulnerable time period for the development of dysglycemia due to this puberty-related transient insulin resistance (Hannon & Arslanian, 2015). Insulin sensitivity decreases during puberty due to hormonal secretion including human growth hormone, testosterone, and estrogen secretion, along with increased fat mass in females (Cree-Green et al., 2013). Studies have shown that insulin resistance occurs prior to puberty, explained by the accumulation of fat and rising insulin-like growth factor (Cree-Green et al., 2013). Insulin resistance peaks during the time period of mid-puberty in normal weight youth; therefore being obese during puberty may enhance the risk for developing T2DM in youth (Cree-Green et al., 2013).

Morbidity & Mortality

The incidence of T2DM in youth has increased drastically over the past 20 years (Nadeau et al., 2016). According to the 2014 National Diabetes Statistics Report, in 2008 to 2009 the incidence of youth (<20 years) was approximately 5,089 new cases (CDC, 2015b). Of the new

cases of T2DM reported in the United States the greatest new cases were among children aged 10 to 19 years (ADA, 2016b). Figure 5 shows the incidence in both T1DM and T2DM among American youth (< 20 years) categorized by race/ethnicity in the years 2008 and 2009.

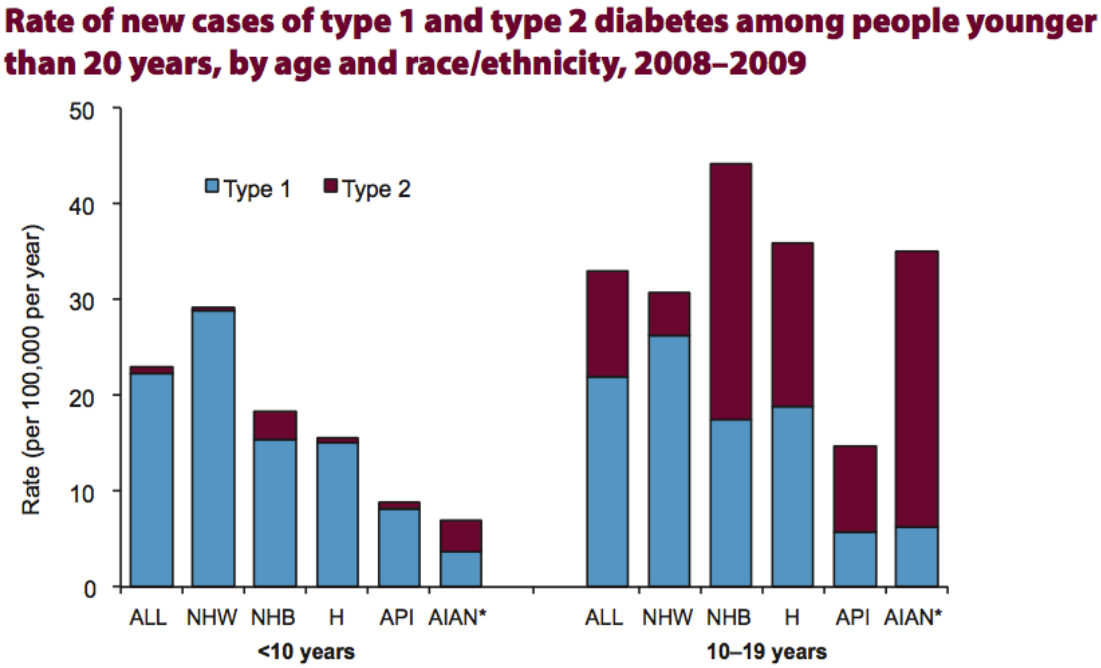

Figure 5. Incidence in 2008 and 2009 for T1DM and T2DM in Americans < 20 years of age. Copied from the 2014 National Diabetes Statistics Report (CDC, 2015b, p. 4).

Figure 5 shows that the 2014 National Diabetes Statistics Report found the highest incidence of T2DM in adolescents (10 to 19 years of age) was identified in the Asian population, followed by the African-American population (CDC, 2015b). Projections of the burden of T2DM in the United States youth population (< 20 years) from the years 2010 to 2050 forecast an increase from 20,203 to 30,111 cases, assuming a constant incidence over time (Hannon & Arslanian, 2015). It is projected that one third of all children today will develop T2DM in their lifetime (Canterbury & Hedlund, 2013). In the most recent epidemiologic analyses, the prevalence T2DM in the pediatric population triples from the age group of 10 to 14 years to the 15 to 18 year age group and affects adolescent females with rates 60% higher than adolescent

males (ADA, 2016b). Similar to the adult population, the transition from normal glucose tolerance to T2DM in youth is preceded by an intermediate stage of prediabetes which is defined by IFG (FPG values of 100-125 mg/dL) or IGT (OGTT values 140-199 mg/dL) (Hannon & Arslanian, 2015). Among United States adolescents (12 to 19 years) prevalence rates of IFG, IGT, and prediabetes were 13.1%, 3.4%, and 16.1%, respectively (Hannon & Arslanian, 2015). The prevalence for prediabetes in overweight adolescents had a (2.6) higher rate of prediabetes than adolescents categorized with a normal BMI (Hannon & Arslanian, 2015).

Current Treatment and Complications for T2DM in Youth

There is an unmet need for evidenced-based pediatric prevention programs specifically targeting diabetes rather than obesity. Prior to the DPP study, the threshold of weight loss necessary for diabetes prevention in adults (5-7%) was not established and the relative impact of pharmaceutical versus behavioral intervention was unknown. Despite the many evidence-based pediatric obesity interventions available (Ely et al., 2017), long-term chronic disease prevention may not be achieved if biological thresholds are not met. The increasing incidence of T2DM in adolescents is a serious public health problem that is complicated by the limited by the choices of effective treatment options (Folsom & Hannon, 2017). Further, studies conducted on the natural history of T2DM in youth show the disease is more aggressive in young people in comparison with the adult populations (Hannon, 2014). Concurrent with the complications of earlier development of T2DM among youth is the pediatric obesity epidemic, which also carries the increased risk of the development of T2DM (Candela, Gutierrez, Dufek, Putney, & Mercer, 2012). Nearly 30-50% of American children diagnosed with T2DM, and nearly all of these are categorized as overweight or obese (Candela et al., 2012). The increased risk for microvascular and macrovascular complications developing earlier in life due to an early onset of T2DM in

youth is an important part of the impetus to increase treatment of prediabetes and T2DM in the youth population (Hannon & Arslanian, 2015).

Barriers to Comprehensive Treatment

There is an unmet need for evidenced-based pediatric prevention programs targeting diabetes rather than obesity. Prior to the TODAY study results, there were few data to guide treatment for prediabetes and/or T2DM in the pediatric population; most recommendations were based on studies in adults with T2DM (Hannon & Arslanian, 2015). The preliminary treatments for adults with prediabetes and/or T2DM are pharmacological treatments including metformin (NIDDK, 2008) and lifestyle interventions, including improved nutrition habits and increased physical activity; these interventions have not been studied extensively among the youth population (Folsom & Hannon, 2017). Currently, the only pharmacological treatments approved for children with T2DM are metformin and insulin (Folsom & Hannon, 2017).

Another complicating factor to implementing lifestyle interventions in children are: their limited participation in the type or quality of food purchased, how the meal is prepared, and/or the location of their home and access to safe places to exercise (Folsom & Hannon, 2017). The treatment of T2DM in youth requires a multifaceted approach through a diabetes team including the patient, family, physician/clinical team, behavioral specialists, dieticians, and school personnel (Hannon & Arslanian, 2015).

Many pediatric lifestyle interventions have focused on youth affected by obesity rather than prediabetes and T2DM (Nadeau et al., 2016). The majority of these interventions focus on individual behavior modification, utilizing health education to target nutrition and physical activity and social cognitive models (Nadeau et al., 2016). Obesity is a major risk factor in the development of prediabetes and T2DM, thus increasing the focus of prevention of prediabetes

and T2DM in pediatric interventions has significant benefits to improve the quality of life of children (Hannon & Arslanian, 2015).

The TODAY study, a multifaceted study (funded by the NIDDK), researched treatment strategies and options for adolescents and youth with T2DM (Linder, Fradkin, & Rodgers, 2013). The results of the TODAY study showed that: primarily, metformin monotherapy provided glycemic control in only half the participants; secondly, that the combination of metformin and rosiglitazone improved the durability of glycemic control; and lastly, that metformin combined with lifestyle intervention was no better than metformin alone in maintain glycemic control (Linder et al., 2013). Further analysis of the data on insulin resistance and secretion derived from serial OGTT in the TODAY study, suggest that early and rapid deterioration of beta-cell function in these youth in comparison with adults newly diagnosed T2DM (Linder et al., 2013). The HEALTHY study (funded by the NIDDK with support from the ADA) demonstrated that population-based programs could lower rates of obesity and hyperinsulinemia in middle school-aged children (Linder et al., 2013). The challenges of effectively treating T2DM in children compound the need for further research into effective prevention of obesity and diabetes (Linder et al., 2013).

The Need for Effective Youth T2DM Prevention

The rising prevalence of overweight children as well as children with type 2 diabetes has prompted the adaptation and development of pediatric diabetes prevention programs that parallel those for adults (Candela et al., 2012). However, these programs are only emergent and are few in number. The following section summarizes and critiques the pediatric DPPs found during the research for this project and their use of theories and research to adapt existing DPPs for youth.

Existing Youth Diabetes Prevention Programs (YDPPs)

There has been increasing research and programs implemented to prevent and treat the early onset of T2DM. A comprehensive review of the literature, about emerging diabetes prevention program was conducted through research databases and youth children hospitals. Three diabetes prevention programs and/or clinics for youth were identified. Their basic characteristics are listed in Table 1 and a summary of strengths and weaknesses for each program follows.

Table 1

Characteristics of Emerging Youth Diabetes Prevention Programs

Programs	*Get a Move On*	*PowerHouse*	Adapted Diabetes Prevention Program	*Bright Bodies*
Affiliation	Indiana University	Indiana University	University of Nevada, Las Vegas	Yale University
Target Audience	>10 years	>10 years	6th, 7th, 8th, & 9th graders	7-16 years
Intervention Setting	Community-Setting	Community-Setting	School Classroom	Community-Setting
Curriculum	Social Cognitive Theory	Social Cognitive Theory	Sociocultural Theory	Smart Moves™
Length/Delivery	Once a Week for 12 weeks	Twice a Week for 16 weeks	Five times a week for 10 weeks	Twice a week for six months

Indiana University: Riley Children's Hospital Diabetes Prevention Clinic

Indiana University School of Medicines' Youth Diabetes Prevention Clinic is operated within Riley's Children Hospital (Riley Children's Health, Indiana University Health, 2017). This clinic is designed to diagnose children and adolescents (> 10 years of age) that present with prediabetes and/or have elevated risk factors for the development of T2DM (Riley Children's Health, Indiana University Health, 2017). The clinical treatment program utilizes the DPP

modified for use with patients and their families (Riley Children's Health, Indiana University Health, 2017). Identified risk factors are family history of T2DM, elevated blood sugar levels, and obesity and many of the adolescents are referred to the program by their primary care doctor (Riley Children's Health, Indiana University Health , 2017). Each patient receives and individualized coaching plan to increase physical activity, consultation with dietician to improve overall diet (Riley Children's Health, Indiana University Health, 2017).

The strengths of the Riley Children's Hospital YDPP include the utilization of core constructs of the NDPP (lifestyle interventions) by providing education about behavioral modification not only to the patient, but to his/her family (Riley Children's Health, Indiana University Health, 2017). Along with modifying the DPP, YDPP clinic also uses goal-setting strategies to implement therapeutic lifestyle changes in both the children and their families (Riley Children's Health, Indiana University Health, 2017). The treatment model aims to prevent T2DM in adolescents at the local, state, and national level with continuous communication with providers (Riley Children's Health, Indiana University Health, 2017). An individualized plan for each patient allows for the accommodation of individualized needs for a patients behavioral change (Riley Children's Health, Indiana University Health, 2017).

The clinic has implemented several programs in order to identify the best methods to prevent diabetes (personal communication, Julie Pike, RD, CDE). The first program, known as *Get a Move On*, emphasized a curriculum of health education sessions centered on education about fruits and vegetables, healthy breakfast, portion sizes, decreasing the amount of sugary drinks and snacks, and eating at home (personal communication, Julie Pike, RD, CDE). Each topic was covered over two weeks and incorporated the mother as gatekeeper to the children's food source (personal communication, Julie Pike, RD, CDE).

Powerhouse, an improved program based on the initial program *Get a Move On*, is a 16-week-long program that began in January 2017. It is aimed at incorporating separate lifestyle interventions for children and their parents. The clinic is measuring the effects these separate, targeted educational interventions have on preventing T2DM in youth (personal communication, Julie Pike, RD, CDE). The purpose of this group intervention is to provide educational sessions that are better tailored for the target learning styles, which differ throughout stages of developments, as well as provide social support (personal communication, Julie Pike, RD, CDE).

University of Nevada, Las Vegas's: Adapted DPP

The University of Nevada, Las Vegas conducted a feasibility case study that modified the NDPP curriculum (CDC, 2016b) for adolescent populations (7^{th} to 10^{th} graders) in a school setting. Modifying the DPP for adolescent use could benefit the fight against the pediatric T2DM epidemic. School-based programs are considered a beneficial approach due to the great amount of time students spend in school-based environments (Candela et al., 2012). Students participated in 45-minute sessions, five days a week, conducted daily during a regular class period for a total of ten weeks (Candela et al., 2012). The study demonstrated that instruction, using the CDC's DPP curriculum specifically tailored to adolescents, positively impacted their dietary knowledge, but not weight Results from this study indicate that the DPP intervention increased positive lifestyle behaviors including improved reported dietary habits and increased reported physical activity. However, this association as only identified in the younger grade levels (7^{th} and 8^{th} graders) (Candela et al., 2012). This was explained by the possible commitment to learning diminishes as adolescents transition to high school and become more focused on social groups and relationships (Candela et al., 2012). The study demonstrated that instruction, using the CDC's DPP curriculum specifically tailored to adolescents, positively

impacted their dietary knowledge, but not weight (Candela et al., 2012). Further analysis of the modified DPP program to identify the proper age group to target with this modification because high school and middle school students have higher levels of disengagement than elementary students as well as increased freedom to make choices about their diet (Candela et al., 2012).

Yale University's: Bright Bodies Weight Management Program for Children

The Bright Bodies Weight Management Program for Children (Bright Bodies) is a weight management program operated through the Yale University Pediatric Obesity Clinic tailored for children ages seven to sixteen years of age (Yale Center for Clinical Investigation and Pediatric Endocrinology, Yale School of Medicine, n.d.). It is a comprehensive program that utilizes the *Smart Moves* program curriculum, which includes nutrition education, behavior modification and exercise (Savoye, 2010). This program is a family-based, lifestyle intervention tailored for inner-city youth and their families (Savoye et al., 2014).

The Bright Bodies program showed success in limiting weight gain and improving body composition, insulin sensitivity, and lipids compared with the control group that received conventional dietary counseling (Savoye et al., 2014).

Bright Bodies conducted another study with a goal to compare the effects of Bright Bodies programs and standard clinical care on glucose tolerance in obese adolescents with elevated OGTT levels (Savoye et al., 2014). Program participants (n=75) were recruited for the study from Yale Pediatric Obesity Clinic to increase screening for IGT in obese children and adolescents being treated by pediatric practices in New Haven, Connecticut (Savoye et al., 2014). The program was administered twice a week for six months which included two 50-minute exercise sessions per week, one weekly weigh-in and 40-minute nutrition/behavior educational sessions (Savoye et al., 2014).

The primary results of the study showed that Bright Bodies program significantly decreased OGTT values in children at high risk for diabetes after six months in comparison with children that received standard of care (Savoye et al., 2014). The findings indicate that the Bright Bodies intervention improved glucose tolerance in obese youth with prediabetes (Savoye et al., 2014). Notably, the curriculum for the Bright Bodies has served as a basis for several pediatric obesity programs throughout the United States and the standardized curriculum has the potential to cut training time, salary costs, and improve a more standardized dissemination of the program (Savoye et al., 2014). Limitations of the Bright Bodies program include the major commitment required from families, communities, and care providers (Savoye et al., 2014).

Discussion and Recommendations

The aim of this project was to identify the best-practices for implementing prevention programs for prediabetes and T2DM due to the critical importance of diagnosing and treating dysglycemia in youth due to the early complications of childhood obesity and T2DM (Nowicak et al., 2011). Currently three programs are utilizing the best practices of the CDC's DPP, including adapted lifestyle interventions that have been proven successful in adults (NIDDK, 2008) and adopting a team approach that includes the patient, their family, physician, and behavioral specialists (Hannon & Arslanian, 2015). The major concern for each of the programs is to include the family and/care provider in the treatment program and to establish a community presence of care, including follow up with pediatrician to regularly monitor a child's progress in maintaining safe glucose levels (personal communication, Julie Pike, RD, CDE). The professional literature seems to place the burden of prevention on healthcare professionals, but it must be a shared responsibility between the family, school, neighborhoods, the food industry, and policy makers (Hannon & Arslanian, 2015).

To facilitate the increased modification and implementation of lifestyle intervention programs to address prediabetes and T2DM in youth, it is essential to conduct follow up studies for the present evidenced-based programs being implemented today. Continued research is needed to improve existing and establish new-evidence based DPP program curricula readily available for dissemination of DPP programs in youth.

In addition to lack of studies outlining YDPP's and there success, there is also a lack of approved pharmacological agents to be used when metformin, the only approved therapy for children, fails in youth (Hannon & Arslanian, 2015). Further identification of pharmacological interventions for prediabetes and/or T2DM in youth is necessary in order to assist reverse prediabetes and/or delay the onset of T2DM in youth in conjunction with YDPPs.

Recommendations developed from this project include modifying and disseminating programs that can be administered at school locations and during school hours in order to limit the obstacles in youth with T2DM like transportation, access to care to identify eligibility criteria, and the reluctance to participate with parents/guardians (Folsom & Hannon, 2017). Long-term physical and psychosocial consequences can stem from developing T2DM in early developmental stages (Folsom & Hannon, 2017). Continued research is needed to improve and establish evidence-based curricula readily available for dissemination of DPP programs for youth. Increased research designed to minimize the gaps in literature about the pathophysiology of T2DM in youth, the ability to reverse prediabetes and delay the onset of T2DM, and increase the availability of and participation in these programs will improve the chances for successful program implementation to combat the epidemic of T2DM in youth within the United States.

References

Abraham, T. M., & Fox, C. S. (2013). Implications of rising prediabetes prevalence. *Diabetes Care*, *36*(8), 2139-2141. doi:10.2337/dc13-0792

American Association for Clinical Chemistry. (2014). *Acidosis and alkalosis.* Lab Tests Online. Retrieved from https://labtestsonline.org/understanding/conditions/acidosis/

American Diabetes Association (ADA). (2013). *History of diabetes.* (2013). Retrieved from http://www.diabetes.org/research-and-practice/student-resources/history-of-diabetes.html

American Diabetes Association (ADA). (2014). *Hyperglycemia.* (2014). Retrieved from http://www.diabetes.org/living-with-diabetes/treatment-and-care/blood-glucose-control/hyperglycemia.html

American Diabetes Association (ADA). (2015). *Diabetes symptoms.* Retrieved from http://www.diabetes.org/diabetes-basics/symptoms/

American Diabetes Association (ADA). (2016a). 2. Classification and diagnosis of diabetes. *Diabetes Care, 39*(S1), *S13-S22*. doi:10.2337/dc16-S005

American Diabetes Association (ADA). (2016b). Statistics about Diabetes: Overall Numbers, Diabetes and Prediabetes. Retrieved from http://www.diabetes.org/diabetes-basics/statistics/

American Diabetes Association (ADA). (2016c). *Diagnosing diabetes and learning about prediabetes.* Retrieved from http://www.diabetes.org/diabetes-basics/diagnosis/

American Diabetes Association (ADA). (2017). 2. Classification and diagnosis of diabetes. *Diabetes Care*, *40*(S1), S11-S24. doi:10.2337/dc17-S005

Basile, K. J., Guy, V. C., Schwartz, S., & Grant, S. (2014). Overlap of genetic susceptibility to type 1 diabetes, type 2 diabetes, and latent autoimmune diabetes in adults. *Current Diabetes Reports, 14*(11), 550.

Bassett, D. R., John, D., Conger, S. A., Fitzhugh, E. C., & Coe, D. P. (2015). Trends in physical activity and sedentary behaviors of United States youth. *Journal of Physical Activity & Health, 12*(8), 1102-1111. doi:10.1123/jpah.2014-0050

Brar, P. C., Mengwall, L., Franklin, B. H., & Fierman, A. H. (2014). Screening obese children and adolescents for prediabetes and/or type 2 diabetes in pediatric practices: A validation study. *Clinical Pediatrics, 53*(8), 771-776. doi:10.1177/0009922814528571

Candela, L. L., Gutierrez, A. P., Dufek, J. S., Putney, L. G., & Mercer, J. A. (2012). Modifying the diabetes prevention program to adolescents in a school setting: A feasibility study. *ISRN Education, 2012*, Article ID 534085. doi:10.5402/2012/534085

Canterbury, M., & Hedlund, S. (2013). The potential of community-wide initiatives in the prevention of childhood obesity. *Diabetes Spectrum, 26*(3), 165-170. doi:10.2337/diaspect.26.3.165

Centers for Disease Control and Prevention (CDC). (2015a). *Basics about diabetes.* Retrieved from https://www.cdc.gov/diabetes/basics/diabetes.html

Centers for Disease Control and Prevention (CDC). (2015b). National Diabetes Statistics Report. Retrieved from https://www.cdc.gov/diabetes/pubs/statsreport14/national-diabetes-report-web.pdf

Centers for Disease Control and Prevention (CDC). (2015c). Body Mass Index. Retrieved from https://www.cdc.gov/healthyweight/assessing/bmi/

Centers for Disease Control and Prevention (CDC). (2016a). *2017 ICD-10-CM diagnosis code.* Retrieved from http://www.icd10data.com/ICD10CM/Codes/R00-R99/R70-R79/R73-/R73.03

Centers for Disease Control and Prevention (CDC). (2016b). *National diabetes prevention program.* Retrieved from https://www-cdc-gov.ezproxy.libraries.wright.edu/diabetes/prevention/prediabetes-type2/preventing.html

Centers for Disease Control and Prevention (CDC). (2016c). *Prediabetes.* Retrieved from https://www.cdc.gov/diabetes/basics/prediabetes.html

Centers for Medicare & Medicaid Services (CMS). (2016, November 2). Medicare Diabetes Prevention Program (MDPP) Expanded Model. Retrieved from https://www.cms.gov/newsroom/mediareleasedatabase/fact-sheets/2016-fact-sheets-items/2016-11-02-2.html

Cree-Green, M., Triolo, T. M., & Nadeau, K. J. (2013). Etiology of insulin resistance in youth with type 2 diabetes. *Current Diabetes Reports, 13l*(1), 81-88. doi:10.1007%2Fs11892-012-0341-0

D'Adamo, E., & Caprio, S. (2011). Type 2 diabetes in youth: Epidemiology and pathophysiology. *Diabetes Care, 34*(2), S161-S165. doi:10.2337/dc11-s212

Ely, E., Gruss, S., Luman, E., Gregg, E., Ali, M., Nhim, K., . . . Albright, A. (2017). A national effort to prevent type 2 diabetes:participant-level evaluation of CDC's national diabetes prevention program. *Diabetes Care 40(6),* 1-11. doi:10.2337/dc16-2099

Evans, A., Ranjit, N., Hoelscher, D., Jovanovic, C., Lopez, M., McIntosh, A., . . . Warren, J. (2016). Impact of school-based vegetable garden and physical activity coordinated health interventions on weight status and weight-related behaviors of ethnically diverse, low-

income students: Study design and baseline data of the texas, grow! eat! go! (TGEG) cluster-randomized controlled trial. *BMC Public Health, 16*, 973-973. doi:10.1186/s12889-016-3453-7

Faguy, K. (2016). Obesity in children and adolescents: Health effects and imaging implications. *Radiologic Technology, 87*(3), 279-302. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26721840

Folsom, L. J., & Hannon, T. S. (2017). Collaboration is key for successful treatment of youth-onset type 2 diabetes. *Journal of Adolescent Health, 60*(4), 360-362. doi:10.1016/j.jadohealth.2016.12.022

Hannon, T. S., & Arslanian, S. A. (2015). The changing face of diabetes in youth: Lessons learned from studies of type 2 diabetes. *Annals of the New York Academy of Sciences, 1353*(1), 113-137. doi:10.1111/nyas.12939

Hannon, T. S. (2014). Research is needed to determine optimal screening methods to lessen the burden of type 2 diabetes in youth. *Journal of Adolescent Health, 54*(2), 117-118. doi:10.1016/j.jadohealth.2013.11.016

Jaacks, L., Siegel, K., Gujral, U., & Narayan, V. (2016). Type 2 diabetes: A 21st century epidemic. *Best Practice & Research Clinical Endocrinology & Metabolism, 30*(3), 331-343. doi:10.1016/j.beem.2016.05.003

Juvenile Diabetes Research Foundation (JDRF). (n.d.). *Type 1 diabetes.* Retrieved from http://www.jdrf.org/about/fact-sheets/type-1-diabetes-facts/

Kelly, S. A., Melnyk, B. M., Jacobson, D. L., & O'Haver, J. (2011). Correlates among healthy lifestyle cognitive beliefs, healthy lifestyle choices, social support, and healthy behaviors

in adolescents: Implications for behavioral change strategies and future research. *Journal of Pediatric Health Care, 25*(4), 216-233. doi10.1016/j.pedhc.2010.03.002

Khardori, R. (2016). *Type 1 diabetes mellitus treatment & management.* Medscape.com. Retrieved from http://emedicine.medscape.com/article/117739-treatment

Kong, A., Luk, A., & Chan, J. (2016). Detecting people at high risk of type 2 diabetes - how do we find them and who should be treated? *Best Practice & Research Clinical Endocrinology & Metabolism, 30*(3), 345-355. doi:10.1016/j.beem.2016.06.003

Linder, B. L., Fradkin, J. E., & Rodgers, G. P. (2013). The TODAY study: An NIH perspective on its implications for research. *Diabetes Care, 36*(6), 1775-1776. doi:10.2337/dc13-0707

Mayo Clinic. (2014). *Type 1 diabetes: Tests and diagnosis.* Retrieved from http://www.mayoclinic.org/diseases-conditions/type-1-diabetes/basics/tests-diagnosis/con-20019573

Mayo Clinic. (2016). *Type 2 diabetes diagnosis & treatment.* Retrieved from http://www.mayoclinic.org/diseases-conditions/type-2-diabetes/diagnosis-treatment/treatment/txc-20169988

Nadeau, K. J., Anderson, B. J., Berg, E. G., Chiang, J. L., Chou, H., Copeland, K. C., . . . Zeitler, P. (2016). Youth-onset type 2 diabetes consensus report: Current status, challenges, and priorities. *Diabetes Care, 39*(9), 1635-1642. doi:10.2337/dc16-1066

National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK*).* (2017). *Diabetes overview.* Retrieved from https://www.niddk.nih.gov/health-information/diabetes

National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). (2008). *Diabetes Prevention Program (DPP).* Retrieved from https://www.niddk.nih.gov/about-niddk/research-areas/diabetes-prevention-program-dpp/pages/default.asp

National Institutes of Health (NIH). (2015). Intervention lowered obesity rate in youth at high diabetes risk, HEALTHY study finds. (Press release, October 02). Retrieved from https://www.nih.gov/news-events/news-releases/intervention-lowered-obesity-rate-youth-high-diabetes-risk-healthy-study-finds

Nowicak, P., Santoro, N., Liu, H., Lartaud, D., Shaw, M., Goldberg, R., . . . Caprio, S. (2011). Utility of hemoglobin A1C for diagnosing prediabetes and diabetes in obese children and adolescents. *Diabetes Care, 34*(6), 1306-1311. doi:102337/dc10-1984

Pippitt, K., Li, M., & Gurgle, H. (2016). Diabetes mellitus: Screening and diagnosis. *American Family Physician, 93*(2), 103-109. Retrieved from http://www.aafp.org/afp/2016/0115/p103.html

Reinehr, T. (2013). Type 2 diabetes mellitus in children and adolescents. *World Journal of Diabetes, 4*(6), 270-281. doi:10.4239/wjd.v4.i6.270

Riley Children's Health, Indiana University Health. (2017). *Youth diabetes prevention program.* Retrieved from https://www.rileychildrens.org/departments/youth-diabetes-prevention-program

Romero, L. F. (2016). Continuing Education. Diabetes: The current state of affairs from a population management view. *Medical Laboratory Observer, 48*(8), 12-20.

Savoye-Desanti, M. (2010). *Smart Moves: A childhood obesity treatment curriculum and model.* Retrieved from http://smartmovesforkids.com/

Savoye, M., Caprio, S., Dziura, J., Camp, A., Germain, G., Summers, C., . . . Tamborlane, W.V. (2014). Reversal of early abnormalities in glucose metabolism in obese youth: Results of an intensive lifestyle randomized controlled trial. *Diabetes Care, 37*(2), 317-324. doi:10.2337/dc13-1571

The Obesity Society. (2016). *Your weight and diabetes.* Retrieved from http://www.obesity.org/content/weight-diabetes

The Office of Disease Prevention and Health Promotion (ODPHP). (2017a). 2008 Physical Activity Guidelines. Retrieved from https://health.gov/paguidelines/guidelines/

The Office of Disease Prevention and Health Promotion (ODPHP). (2017b). Dietary Guidelines 2015-20120. Retrieved from https://health.gov/dietaryguidelines/2015/guidelines/executive-summary/

Tuso, P. (2014). Prediabetes and lifestyle modification: Time to prevent a preventable disease. *The Permanente Journal, 18*(3), 88-93. doi:10.7812/TPP/14-002

WebMD. (2017). *Types of diabetes mellitus.* Retrieved from http://www.webmd.com/diabetes/type-2-diabetes-guide/type-2-diabetes#1

Williams, A. N., Konopken, Y. P., Keller, C. S., Castro, F. G., Arcoleo, K. J., Barraza, E., . . . Shaibi, G. Q. (2017). Culturally-grounded diabetes prevention program for obese Latino youth: Rationale, design, and methods. *Contemporary Clinical Trials, 54*, 68-76. doi:10.1016/j.cct.2017.01.004

World Health Organization (WHO). (2017). Childhood Overweight and Obesity. Retrieved from http://www.who.int/dietphysicalactivity/childhood/en/

Yale Center for Clinical Investigation and Pediatric Endocrinology, Yale School of Medicine. (n.d.). *Bright Bodies Weight Management Program for Children.* Retrieved from http://www.brightbodies.org/

Zeitler, P., Hirst, K., Pyle, L., Linder, B., Copeland, K., Arslanian, S., . . .Kaufman, F. (2012). A clinical trial to maintain glycemic control in youth with type 2 diabetes. *New England Journal of Medicine, 366*(24), 2247-2256. doi:10.1056/NEJMoa1109333

Zilanawala, A., Davis-Kean, P., Nazroo, J., Sacker, A., Simonton, S., & Kelly, Y. (2015). Race/ethnic disparities in early childhood BMI, obesity and overweight in the United Kingdom. *International Journal of Obesity, 39*(3), 520-529. doi:10.1038/ijo.2014.171

Zoorob, R., Buchowski, M., Beech, B., Canedo, J., Chandrasekhar, R., Akohoue, S., & Hull, P (2013). Healthy families study: Design of a childhood obesity prevention trial for Hispanic families. *Contemporary Clinical Trials, 35*(2), 108-121. doi:10.1016/j.cct.2013.04.005

Appendix A: List of Competencies Met in CE

Wright State Program Public Health Competencies Checklist

Assess and utilize quantitative and qualitative data.
Apply analytical reasoning and methods in data analysis to describe the health of a community.
Apply behavior theory and disease prevention models to develop community health promotion and intervention programs.
Communicate public health information to lay and/or professional audiences with linguistic and cultural sensitivity.
Make evidence-informed decisions in public health practice.
Evaluate and interpret evidence, including strengths, limitations, and practical implications.
Demonstrate ethical standards in research, data collection and management, data analysis, and communication.

Concentration Specific Competencies Checklist

Health Promotion and Education:	
Area 1: Assess Needs, Assets and Capacity for Health Education	
1.3	Analyze factors that foster or hinder the learning process
1.4	Identify factors that foster or hinder skill building
1.5	Analyze factors that foster or hinder skill building
1.6	Synthesize assessment findings
Area 2: Plan Health Education Programs	
2.1	Use assessment results to inform the planning process
2.2	Select planning model(s) for health education
2.3	Develop goal statements
2.7	Organize health education into a logical sequence
Area 3: Implement Health Education	
3.5	Use evaluation findings to plan future training
Area 4: Conduct Evaluation and Research Related to Health Education	
4.1	Create purpose statement
4.2	Develop evaluation/research questions
4.3	Assess the merits and limitations of qualitative and quantitative data collection for research
4.6	Develop data analysis plan for research
4.9	Disseminate research findings through professional conference presentations
Area 5: Manage Health Education Programs	
5.7	Use communication strategies to obtain program support
5.10	Synthesize data for purposes of reporting
Area 6: Serve as a health education resource person	
6.4	Identify existing resources that meet training needs
6.5	Use learning theory to develop or adapt training programs
6.8	Use a variety of resources and strategies